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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 : F24F 3/16

A1

(11) International Publication Number: WO 94/17336

(43) International Publication Date: 4 August 1994 (04.08.94)

(21) International Application Number: PCT/US94/00900

(22) International Filing Date: 26 January 1994 (26.01.94)

(30) Priority Data:

010,534	28 January 1993 (28.01.93)	US
033,892	19 March 1993 (19.03.93)	US

(81) Designated States: CN, JP, KR, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.

(71) Applicant: INTELLIGENT ENCLOSURES CORPORATION [US/US]; 4351 Shackleford Road, Norcross, GA 30093 (US).

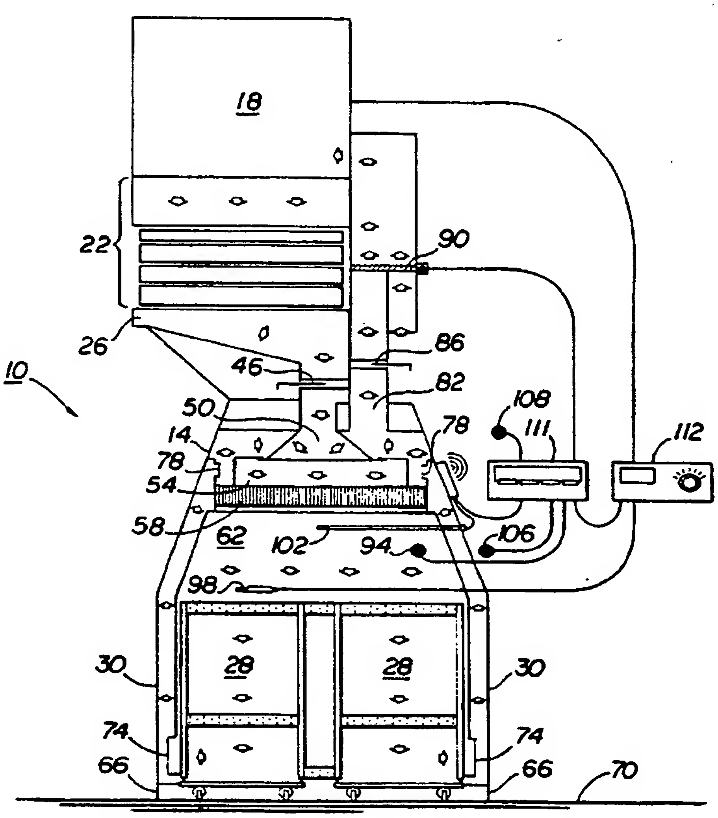
(72) Inventors: GENCO, Robert, M.; 1367 Fairview Road, Atlanta, GA 30306 (US). MARVELL, Greg, A.; 2127 Riverbiroh Court, Lawrenceville, GA 30244 (US). MILLER, David, E.; 506 Calibre Woods Drive, Atlanta, GA 30329 (US). MUNDT, Gregory, K.; 3699 Montrose Pond Court, Duluth, GA 30136 (US).

(74) Agents: RUSSELL, Dean, W. et al.; Kilpatrick & Cody, 1100 Peachtree Street, Suite 2800, Atlanta, GA 30309-4530 (US).

(54) Title: ENVIRONMENTAL CONTROL SYSTEM

(57) Abstract

An environmental control system (10) including a modular isolation chamber (14) together with associated atmospheric regulatory equipment (18) for fabricating or processing of semiconductors and other products. The work pieces and processing or other machinery (28) are isolated from the remainder of the rooms in which they are located, decontamination of much of each room is not required. Use of the portable, modular chambers also permits increased control over particulate contaminates and individualized regulation of differing processing environments within a single room. Other chambers are adapted to supply mixed vertical laminar flow (VLF) and horizontal laminar flow (HLF) over the work pieces.



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ENVIRONMENTAL CONTROL SYSTEM

FIELD OF THE INVENTION

This invention relates to environmental control systems and more particularly to enclosures for regulating atmospheric conditions in areas surrounding, e.g., processing equipment and in material transportation and handling aisles used or useful in a variety of industries.

BACKGROUND OF THE INVENTION

Fabricating semiconductors chips is a multi-step process. Silicon wafers, sliced from a crystal ingot, initially are lapped flat and polished to a mirror-like finish. A layer of single crystalline silicon subsequently is grown on each wafer and the wafers oxidized at elevated temperatures approaching 1000° C. A light-sensitive, "photo-resist" coating then may be applied to each wafer and a wafer stepper used to expose the photo-resist coating. Exposing the coating produces multiple prints containing images of several integrated chips on each wafer.

Following exposure, the photo-resist coatings are developed and baked to harden the patterned prints onto the silicon wafers. The wafers then contact a reactive gas discharge, etching exposed portions of the wafers, before having ionized boron atoms or other impurities implanted into the patterns. A low temperature (350° C) plasma discharge deposits silicon dioxide on the wafers at low pressure, while circuit component contacts may be made by depositing onto the wafers a thin aluminum or similar metallic film. Each wafer

later may be cut into multiple semiconductor chips using a precision diamond saw and the chips attached to packages having contact leads and wire connections. Finally, each chip is then encapsulated in plastic for mechanical and environmental protection.

Because even microscopic airborne impurities can degrade the quality and yield of the fabricated chips, many of these manufacturing steps, including those of applying the photo-resist coating to the wafers and exposing integrated chip images on the coatings, are performed in facilities called "clean rooms." The atmospheres of these clean rooms generally are regulated to limit the numbers and types of particles capable of contacting the silicon wafers. Bodies of workers operating in clean rooms, for example, typically are enveloped by sterile clothing to prevent skin, hair, and other personal particulate matter from being deposited on the wafers. Additional Humidity/Ventilation/Air Conditioning (HVAC) equipment may be used to condition air within the clean rooms to reduce particle concentrations resulting from other sources of contamination such as the wafer processing and handling machinery.

An average manufacturing facility may include as many as two hundred pieces of processing and handling equipment for fabricating semiconductor chips. To accommodate both the various equipment used to process the wafers and wafer-handling personnel, the size of many clean rooms frequently may approach 20,000 ft^2. Such rooms are costly to construct, requiring sophisticated monitoring and air conditioning

equipment to regulate, even moderately, the large-scale environments. Moreover, although clean rooms may be erected to meet present governmental and industry standards mandating less than or equal to 7.5 particles of 0.2 microns or larger per cubic foot, many do not, and cannot, be constructed to fulfill the more rigorous decontamination standards required to produce, for example, 64-megabit dynamic random-access memory chips (DRAMs). Existing clean room technology similarly cannot protect work pieces and material-handling personnel from many microscopic contaminates, including bacteria and viruses, present in the medical, pharmaceutical, biotechnological, food preparation, aerospace, and other processing industries.

SUMMARY OF THE INVENTION

The present invention provides a series of modular, connectable isolation chambers and associated atmospheric control equipment as an alternative to the traditional clean room. Use of these portable, modular chambers, into which specific pieces of semiconductor or other processing machinery or material transportation and handling equipment may be placed as desired, permits increased control over organic and inorganic particulate contaminates at least as small as 0.12 microns while reducing the cost associated with maintaining multiple suitable environments for processing to occur. Because the work pieces and machinery are isolated from the remainder of the rooms in which they are located, decontamination of much of each room is not required.

Similarly, isolating the work pieces and equipment from human operating personnel eliminates the need for workers to wear protective clothing, potentially improving health and safety conditions. The connectable nature of the portable chambers also permits easy rearrangement when equipment or other requirements change.

In one closed-loop embodiment of the invention, air or other fluid flowing in laminar fashion over the processing equipment may be recirculated through airtight cover ducts such as those illustrated in U.S. Patent No. Des. 331,117. The cover ducts also allow access to the interiors of the chambers for servicing and maintaining the equipment as required. The invention includes sensors and regulating equipment designed to maintain constant (positive) pressure within the chambers, preventing contaminated air or other fluid from entering through an opened cover duct or other access means during product loading or servicing. Filtration systems and particle sensors also are included to monitor and reduce particular contaminates present within each module, while temperature and humidity sensors provide information concerning these variables to the HVAC equipment or an operator control display. Precisely controlling the pressure, temperature, and humidity within each chamber helps prevent, for example, unwanted thermal expansion of the products or misalignment of sensitive equipment and undesired changes in the viscosity of the photo-resist coating. If one or multiple modules are utilized, a unitary damper also may be included to supply "make up" air or other fluid to the common HVAC

equipment as necessary. Various lips, skirts, and flanges permit virtually any number of individual modules to be connected and sealed, minimizing wasted space in enclosing differing quantities of processing or other equipment.

In addition to the airtight cover ducts, the recirculatory system of the present invention includes a molded plenum for isolating supply air or other fluid from exhaust returning through the cover ducts and a filter housing into which a replaceable fiberglass ULPA or other filter is positioned. Following replacement of the filter, a compressive, inflatable seal may be used to seat the filter into the housing, thereby forcing the supply air or fluid through the filter before contacting the wafer processing or other equipment. A nozzle formed in each cover duct funnels exhaust through suitable piping and dampers, returning it to the HVAC equipment for reuse.

It is therefore an object of the present invention to provide a series of modular, connectable chambers for isolating work pieces and processing or other equipment from airborne contaminates.

It is an additional object of the present invention to provide a series of modular chambers which, when connected to associated atmospheric control equipment, function as an alternative to the traditional clean room.

It is another object of the present invention to provide increased control over particulate contaminates while reducing the cost associated with maintaining existing processing environments.

It is yet another object of the present invention to connect multiple isolation modules and permit easy rearrangement of the modules when processing equipment or other requirements change.

It is an additional object of the present invention to provide means for monitoring characteristics of and filtering, controlling, and recirculating the air or other fluids within the modular enclosures.

It is a further object of the present invention to provide means for individually regulating differing processing environments within the same room or facility.

It is another object of the present invention to provide a system using mixed vertical laminar flow (VLF) and horizontal laminar flow (HLF).

Other objects, features, and advantages of the present invention will become apparent with reference to the remainder of the written portion and the drawings of this application.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an elevational view of a series of modular isolation chambers of the present invention together with associated environmental control equipment.

FIG. 2 is a cross-sectional, partially schematicized view of a modular isolation chamber and associated controls taken principally along lines 2-2 of FIG. 1.

FIG. 3 is an expanded cross-sectional view of the modular isolation chamber of FIG. 2.

FIG. 4 is a perspective, partially sectioned view of a chemical vapor filtration (CVF) system forming part of the environmental control equipment of FIG. 1.

FIG. 5 is an exterior elevational view of a cover duct forming part of the modular isolation chamber of FIG. 2.

FIG. 6 is an interior elevational view of the cover duct of FIG. 5.

FIG. 7 is an end elevational view of the cover duct of FIG. 5.

FIG. 8 is a top plan view of the cover duct of FIG. 5.

FIG. 9 is a bottom plan view of the cover duct of FIG. 5.

FIG. 10 is a perspective view of a portion of an alternate modular isolation chamber of the present invention.

FIG. 11 is a cross-sectional view of the alternate chamber of FIG. 10, together with associated environmental control equipment, shown connected to the chamber of FIG. 2.

FIGS. 12-18 are illustrations of other chambers or enclosures adapted to supply mixed VLF and HLF.

FIG. 19 is an exploded perspective view of a panel of the chambers or enclosures of FIGS. 12-18.

DETAILED DESCRIPTION

FIG. 1 illustrates the environmental control system 10 of the present invention. Included in system 10 are one or more isolation chambers 14 as well as HVAC equipment 18, at least one CVF filter structure 22, and one or more supply ducts 26. Alternatively, existing clean rooms may be modified by connecting chambers 14 and other necessary components to any

existing (compatible) central HVAC equipment, or to localized HVAC equipment such as products of Parameter Generation and Control, Inc., should any of this equipment already be in place. Modular chambers 14 enclose various processing or other machinery or equipment 28 (FIG. 2), protecting the machinery and work pieces from airborne contaminates while permitting variable environments to be created for differing equipment 28 types. Because equipment 28 is isolated from the remainder of any room in which it is located, decontamination of the remaining space in the room is optional and not required. Using chambers 14 also eliminates the need for workers to wear protective clothing unless accessing the interiors of the chambers 14 themselves.

Also shown in FIG. 1 are cover ducts 30 and a common "make up" air duct 34 for supplying uncirculated air or other fluid to HVAC equipment 18 when necessary or desired. At least one cover duct 30 is associated with each chamber 14 to permit servicing of equipment 28 located within the chamber 14. Cover duct 30 may include window 38 and latches 42 to permit easy access to the chamber 14 interior, either merely by opening window 38 or by removing the cover duct 30 itself. Latches 42 similarly permit cover duct 30 to remain closed when equipment 28 operates.

The arrows shown in FIG. 2 illustrate the recirculating fluid flow of system 10. In an embodiment of system 10 consistent with FIG. 2, air or other fluid pressurized and conditioned by HVAC equipment 18 flows through CVF filter structure 22 into supply duct 26. If supply damper 46 is

open, the fluid flows through supply duct 26 into plenum 50 and then into housing 54, which contains particulate filter 58. The twice-filtered fluid subsequently travels into the interior 62 of chamber 14, where it flows in laminar fashion over (and, if desired, through and around) equipment 28, permitting continued operation of the equipment 28 and removing particles which might otherwise contact the silicon wafers or other work pieces being processed or acted upon by equipment 28. As shown in FIGS. 1-2, chamber 14 may have a skirt 66 for sealing it to the floor 70, thereby precluding fluid entry or exit which otherwise could occur. If a non-recirculating, single-pass system is preferred, skirts 66 may be removed to allow egress of the pressurized air or other fluid. Skirts 66 or other suitable means may also be used to retain in place the frame 72 containing equipment 28.

After contacting and removing particles from equipment 28 (and assuming skirts 66 are utilized), the fluid--now exhaust--flows into lower openings 74 of cover ducts 30. Cover ducts 30, which are hollow (see also FIGS. 3 and 6), permit the exhaust to travel through them to their upper openings or nozzles 78. Nozzles 78 funnel the exhaust into areas of chamber 14 isolated from filter 58 and equipment 28 and through exhaust duct 82 for reentry into HVAC equipment 18. Exhaust damper 86 may be used to prevent exhaust from reentering HVAC equipment 18 (and thereby set the level of positive pressure in chamber 14 or, in certain circumstances, adjust and maintain the positive pressure, as when window 38 is open or cover duct 30 is removed). Unitary make-up damper

90, also shown in FIG. 2 and connected to make up duct 34, may be used as an alternative pressure control and to supply a constant quantity of air or other fluid to HVAC equipment 18 when, for example, window 38 is open or one or more of exhaust dampers 86 are closed.

FIG. 2 further illustrates some of the monitoring and control equipment associated with system 10. Included within interior 62 of chamber 14 may be sensors 94, 98, and 102 for sensing, respectively, the pressure, temperature and humidity, and number of particles present in the supply air or fluid entering chamber 14. An external pressure sensor 106 and ambient temperature and humidity sensor 108 may be located outside chamber 14, permitting determination of the pressure, temperature, and humidity differentials within and without the chamber 14. Each of sensors 94, 98, 102, 106, and 108 may be connected to one or both of controls 111 and 112.

As detailed in FIG. 2, control 112 is connected to HVAC equipment 18 and is capable of varying the velocity of the conditioned supply air or other fluid exiting the HVAC equipment 18 in response to information obtained from one or more of sensors 94, 98, 102, 106, and 108. Control 111, which may be used to open or close any or all of dampers 46, 86, and 90, functions to balance the supply and exhaust air or other fluid flowing through system 10 and thereby maintain constant (or other desired) pressure within each chamber 14. As noted earlier, maintaining a constant positive pressure within a chamber 14 is useful in preventing unfiltered air or other fluid from entering through an open cover duct 30 or window 38

when, for example, processing equipment 28 is serviced. In various embodiments of system 10 either or both of controls 111 and 112 may be or include conventional computers capable of displaying conditions within chamber 14 and providing alarms, data logging, and other functions as appropriate or desired. Controls 111 and 112 also may be used to create unique environments within each chamber 14 of a multi-chambered system 10 as required by the corresponding types of equipment 28 enclosed.

Additional detail concerning chamber 14 and associated equipment is provided in FIG. 3. Included in FIG. 3 are seal 110, lips 114, and beams 118. Seal 110, which may be made of inflatable rubber or similar material, engages the upper periphery of filter 58 and compressively seats (and seals) the filter 58 within housing 54. Together with plenum 50 (which may be molded to have an inverted funnel shape), filter 58, seal 110, and housing 54 isolate the supply air or other fluid entering through supply duct 26 from the exhaust exiting nozzles 78. Moreover, because seal 110 is inflatable, sufficient space within housing 54 can be created to remove filter 58 (should it need to be evaluated or replaced) merely by deflating the seal 110. To prevent unwanted contamination of the interior 62 of chamber 14, the inflation stem of seal 110 may be positioned in the exhaust area of chamber 14 isolated from the supply air or other fluid. Lips 114 permit each chamber 14 to slide onto and attach to a pair of horizontally-positioned "I"-shaped (or similar) beams or supports 118, allowing multiple chambers 14 to be connected in

series as detailed in FIG. 1. Various "T"-shaped or other sealing or fastening devices may be used to seal the peripheries of adjoining chambers 14 and create an essentially unitary structure for enclosing clusters of compatible equipment 28. As is readily apparent, addition, deletion, and rearrangement of chambers 14 may occur merely by sliding the modular chambers 14 on and off supports 118.

FIG. 4 details a typical CVF filtration structure 22 of system 10. Included in filtration structure 22 are frame 122, seal 126, and one or more filters 130a-n. Frame 122, which may be tiered to accommodate multiple filters 130, may have its upper periphery sealed to structure 22 by seal 126 which, like seal 110, can be inflated for easy placement and removal of the filters 130. Frame 122 and structure 22 also may contain ports 134 to allow probes to sample air or other fluid passing through various filters 130. Also illustrated in FIG. 4 is an upper port 138 for conditioned air or other fluid to enter structure 22 from HVAC equipment 18. A lower port (not shown) permits the fluid to exit structure 22 into supply duct 26.

In at least one embodiment of system 10, structure 22 contains four spaced filters 130, a one-inch thick fiberglass ASHRAE filter (130a), two one-inch thick activated charcoal filters (130b and 130c), and a two-inch thick fiberglass ASHRAE filter (130d), positioned from top to bottom within structure 22. These filters 130, while trapping certain particles, also absorb organic and other chemicals which might otherwise pass through filter 58 (which typically is a

fiberglass ULPA or similar filter or may be an Ultra Filter provided by Y Square Ltd. of San Clemente, California). The lowermost ASHRAE filter 130d additionally can be used to trap and thereby prevent any charcoal particles from exiting structure 22. Referring to FIG. 1, filters 130 may be placed in a openable drawer forming part of structure 22 if desired to facilitate filter 130 access and replacement.

FIGS. 5-9, which correspond to FIGS. 2-6 of U.S. Patent No. Des. 331,117, illustrate cover duct 30 of system 10. As seen from its exterior (FIG. 5) and discussed earlier, cover duct 30 includes window 38 and latches 42 for permitting access to equipment 28 and easy attachment and detachment of the cover duct 30 to and from chamber 14. Feet 142 are designed to engage corresponding plates in chamber 14, helping to seal cover duct 30 to the chamber 14 when in place. Gasket 146, which contacts the exterior of chamber 14, similarly helps seal cover duct 30 to the chamber 14. Hinges 150 and handle 152 (FIG. 7) allow window 38 to be opened and closed from outside chamber 14, and cover duct 30 may be made of lightweight plastic for ease of handling when removed from chamber 14.

FIG. 6 provides additional detail concerning the fluid recirculation function performed by cover duct 30. As noted earlier, lower opening 74 serves to intake exhaust which has passed over equipment 28. The pressurized exhaust then is conveyed through the hollow interior of cover duct 30 to nozzle 78, from which it may be passed to suitable piping such as exhaust duct 82 and subsequently reused. If recirculation

is not desired, however, either or both of lower opening 74 and nozzle 78 may be occluded. Fasteners 154 illustrated in FIG. 6 secure gasket 146 to cover duct 30.

Because operating costs can be decreased by conditioning lesser quantities of air or other fluid, the dimensions of chamber 14 and other components of system 10 relative to the size of a traditional clean room form one of many important features of the present invention. In marked contrast to existing clean rooms, for example, selected embodiments of chamber 14 may be as small as (or on the order of) 52"x19"x70". FIGS. 2-3 illustrate an embodiment of chamber 14 sufficiently long to accommodate two adjacent pieces of equipment 28. Because each chamber 14 of the selected embodiments may be as narrow as 19" in width, determination of the number of chambers needed to enclose a series or cluster of equipment may be made relatively precisely, resulting in minimal or no wasted space. The substantially A-shaped exterior of chamber 14 shown in FIGS. 2-3 further decreases the unused space within chamber interior 62 while not obstructing the flow of fluid.

Unlike existing clean room technology, the decontamination capability of system 10 of the present invention is designed to meet or exceed Class 1 requirements of (U.S.) Federal Standard 209D for "Clean Room and Work Station Requirements, Controlled Environment" (June 15, 1988), providing less than 7.5 particles per square foot of size greater than or equal to 0.16 microns. System 10 also can regulate particle contaminates as small as 0.12 microns,

making it suitable for use in a variety of industries (including medical, pharmaceutical, biotechnological, food preparation, aerospace, and other industries) in addition to that of semiconductor fabrication. Other relevant parameters for which an embodiment of system 10 meeting Class 1 specifications is designed include:

Air velocity	50-135 ft/min
Filter 58 efficiency	99.9997%
Filters 130 efficiency	99.99%
Relative Humidity	35-65% RH
Control Constancy	+1% RH
Temperature	20-26° C
Control Constancy	+.10° C
Pressure	0.05" - 0.23" + 0.05" H_2O Ga.
Sound Level	65 dBa at 5 ft (average)

FIGS. 10-11 illustrate an alternative system 210 of the present invention which may enclose clean aisles, hallways, tunnels, or equivalent areas within facilities and permit chambers 14 to interface with, e.g., material transporting and handling robots or personnel. As shown in FIG. 10, system 210 may include a chamber 214, fluid supply plenum 218, filters 222, and a material transportation system 226. FIG. 11 also details environmental control equipment 230, including HVAC equipment 234, filters 238, and dampers 242 and 246, connected to chamber 214. Chamber 214 includes a perforated floor 250 and hollow walls or doors 254 which permit fluid to flow from

equipment 230 through the floor 250 and be recirculated using the doors 254 and damper 246. Base plates 258 and other supports may be used to raise perforated floor 250 while isolating floor 250 from the remainder of the room in which it is located. To provide laminar flow throughout the interior of chamber 214, a diffuser 262, of size approximately the width of chamber 214, may be positioned immediately below filter 222.

Chamber 214 may be used to enclose the material transportation and handling system 226, including robot 266. FIG. 11 illustrates silicon wafers 270 being transported in cassettes 274 over monorails 278 and 282 to robot 266. Robot 266, functioning as an elevator in FIG. 11, then transports cassettes 274 via isolation sleeve 286 to one or more selected chambers 14, where the cassettes may be processed as appropriate by equipment 28. Should material handling system 226 be repositioned within chamber 14, however, supply plenum 218 and filters 222 are designed so as to fit flush against and be sealed to chamber 214.

Chamber 214, like chamber 14, provides a connectable, modular means for isolating controlled areas, equipment--including processing, material handling and transportation, and other equipment--and, as shown in FIG. 11, personnel (if necessary), from ambient, contaminated air in the remainder of the rooms in which they are located. Chambers 14 and 214, connectable via sleeve 286, can thus provide a complete system for isolating work pieces during the entirety of their processing. The modular construction of chambers 14 and 214

and results achieved while employing systems 10 and 210, moreover, permit systems 10 and 210 to be used in a variety of different applications and in a variety of industries. Systems 10 and 210 also accommodate numerous material handling mechanisms, including the Standard Mechanical Interface (SMIF) technology of, e.g., Asyst Technologies, Inc., and both manual and automated handling schemes. Finally, many of the features of chambers 14 and 214 may be interchangeable, so that, for example, chamber 14 may include a diffuser 262 (see FIG. 11) to assist in providing laminar flow throughout the substantially A-shaped chamber 14, or a perforated floor 250 designed to recirculate fluid through openings in the bottoms of modified cover ducts 30.

MIXFLOW STORAGE ENCLOSURE DESCRIPTION

The enclosures 315 illustrated in FIGS. 12-18 are Class 1 (0.2μm) one-pass/mixflow (VLF-Vertical laminar flow and HLF-Horizontal laminar flow) designs and draw air from a HVAC temperature/humidity unit which will then draw make-up air (100%) from the facility ambient air. The enclosure 315 will be located in an open ballroom cleanroom (Class 1-100K, +/- 10°F or greater, +/- 15% or greater). The enclosure 315 will employ ULPA filtration (99.9997%) at the VLF and HLF areas feeding the product storage unit.

Panels will be provided on all sides of the frame and attached to the frame via suitable captured fastening methods (e.g. male panel fasteners to the female frame fasteners). The panel sizes can be determined based on the optimum modular coverage over the product storage unit configurations with the

fewest panel sizes. The panels can be double-wall sided to distribute supply air. They can be fabricated of sheet metal (epoxy painted) or sheet aluminum (epoxy painted) or molded plastic panels depending on the final design. Panels can be mounted to an aluminum extruded inner frame which holds a neoprene gasket (for panel-to-panel) sealing and a two plate manually adjustable aluminum supply air damper. A suitable inner frame is then mounted to the product storage unit frame.

A common supply duct fabricated from, for example, galvanized sheet steel can be employed and ducted to the HVAC unit. In addition, a manual I/O air shower can be provided at the load/unload ports. This enclosure 315 can also include safety interlocks for the front and rear covers and the I/O, ionization bars, and lighting.

MIXFLOW STORAGE ENCLOSURE OPERATION

The enclosure supply air is discharged both vertically, from the top of the enclosure 315, and horizontally from the front and rear, via the double-wall side panels. For improved management the air flow of the VLF stream will typically be set at a higher velocity (60-90 FPM) than the HLF stream (15-20 FPM). This design can serve to drive air more efficiently across the box/cassette area and reduce turbulence as the two HLF streams, front and rear, merge with the VLF stream. Adjusting the VLF and HLF supply air dampers along with the corner transition supply air dampers allows for air flow optimization. In addition, the upper section of the enclosure 315 can be set at a slightly higher velocity than the lower section. This will accelerate the air stream toward the

exhaust vents located at the lower perimeter of the enclosure 315. Exhaust vent fans can be controlled in order to reduce pockets of turbulence within the enclosure 315 and to maintain ideal pressurization of the interior of the enclosure 315.

As shown in FIG. 12, enclosure 315 comprises supply duct 287, corner transition region 288, corner transition supply dampers 294 and side walls or panels 289. Also illustrated are components of panel 289, including filters 292 and supply dampers 295. Supply dampers 295 may be perforated sheets adapted to slide relative to each other to vary the aggregate number or size or perforations through which fluid may flow, thereby permitting variable fluid flow into enclosure 315. Panel 289 (see also FIG. 19) further includes front cover 289a, cap 289b, and rear cover 289c, and may be attached to the remainder of enclosure 315 using fastener assembly 320. Filters 292 may, but need not, be 0.75" ULPA filters.

FIG. 13 furnishes additional detail respecting the elements of enclosure 315, including the HLF flow 290, the VLF flow 291 through supply duct 287, (ULPA or other) filter 291a, and damper 293, and side (exit) relief vents 296. Enclosure 315 may further include flanges 297 or other suitable means for sealing the enclosure 315 to floor F, and product storage areas 292a (such as wafer cassettes or wafer cassette boxes) are also shown. FIG. 14 illustrates fluid supply 298, which includes blower 299 and valve 300.

FIGS. 15-18 illustrate variations of enclosure 315. Shown in FIGS. 15-16, for example, are exhaust fans 305 that may be used in connection with relief vents 296. Embodiments

of enclosure 315 consistent with FIGS. 17-18, by contrast, use bottom relief vents 306 rather than (or in addition to) side relief vents 296. Fluid exiting enclosure 315 through bottom relief vents 306 may flow through appropriate openings 310 in floor F and be recirculated (if desired). Like supply dampers 295, side relief vents 296, bottom relief vents 306, dampers 293, and transition supply dampers 294 may also be sets of perforated sheets adapted to slide relative to each other.

The foregoing is provided for purposes of illustration, explanation, and description of embodiments of the present invention. Modifications and adaptations to these embodiments will be apparent to those skilled in the art and may be made without departing from the scope or spirit of the invention.

What is claimed is:

1. A modular chamber having a bottom and comprising a plurality of fluid supplies, means for controlling mixed fluid flow from the supplies through the chamber using vertical and horizontal air flow panels, a product storage area within the chamber, and fluid relief vents at the bottom.

2. A modular chamber, for enclosing a work piece and isolating it from the remainder of the room in which the chamber is located, comprising:

a. a section defining a first aperture for permitting fluid to enter the chamber;

b. a filter, removably positioned within the chamber, for decontaminating the entering fluid;

c. means, associated with the chamber, for causing the decontaminated fluid to flow over the work piece in both vertical and horizontal laminar fashion; and

d. a second aperture for permitting the flowing fluid to exit the chamber.

3. A chamber, for enclosing a work piece and isolating it from the remainder of the room in which the chamber is located, comprising:

a. a duct for supplying fluid to the chamber;

b. means for causing a first portion of the fluid to flow vertically and in laminar fashion over the work piece;

c. means for causing a second portion of the fluid to flow horizontally and in laminar fashion over the work piece; and

d. an aperture for permitting the first and second portions of the fluid to exit the chamber.

4. A chamber according to claim 3 in which the horizontally-flowing fluid causing means comprises a plurality of perforated elements, at least one of which of moveable relative to another.

5. A chamber according to claim 4 in which the vertically-flowing fluid causing means comprises a plurality of perforated elements, at least one of which of moveable relative to another.

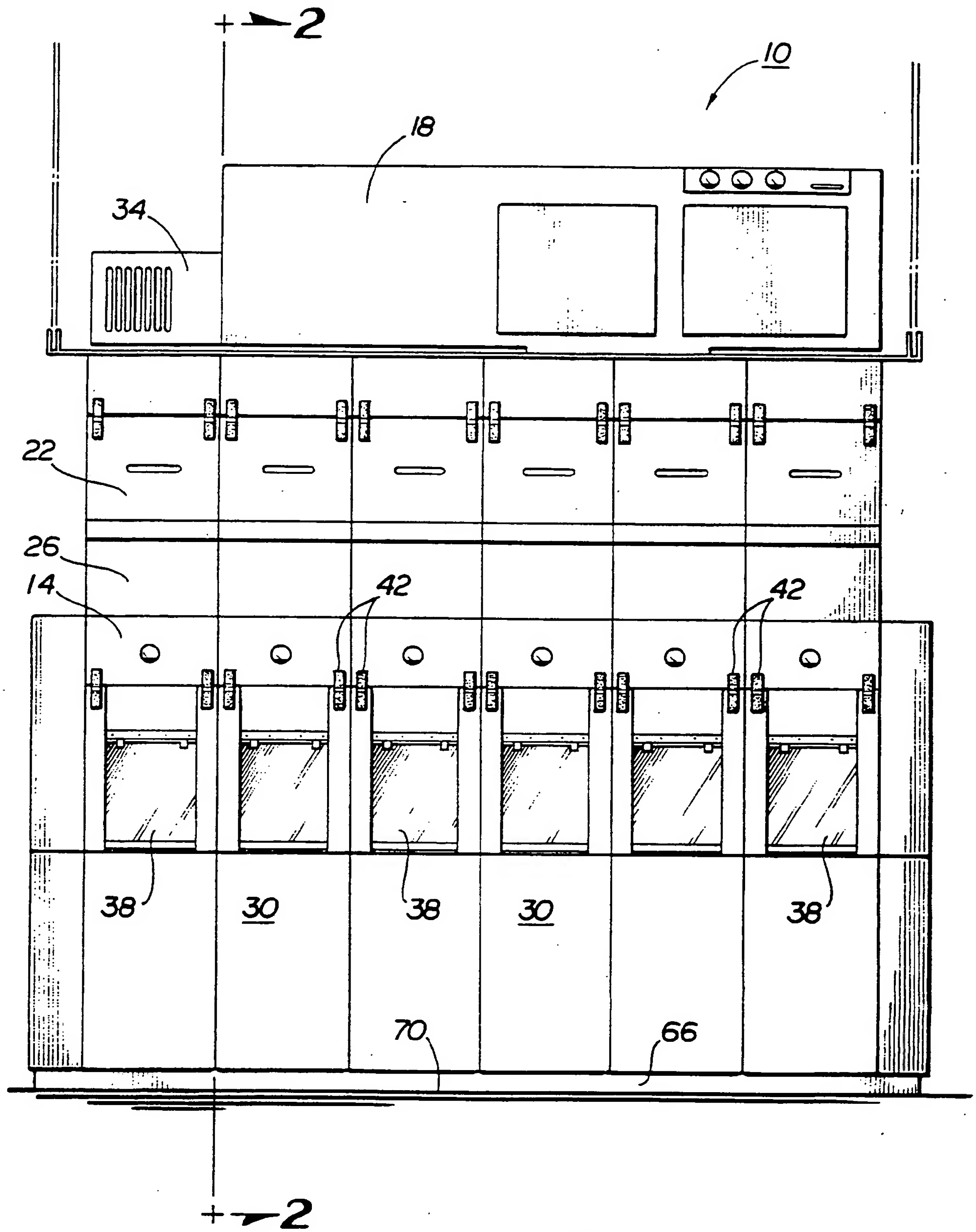

FIG 1

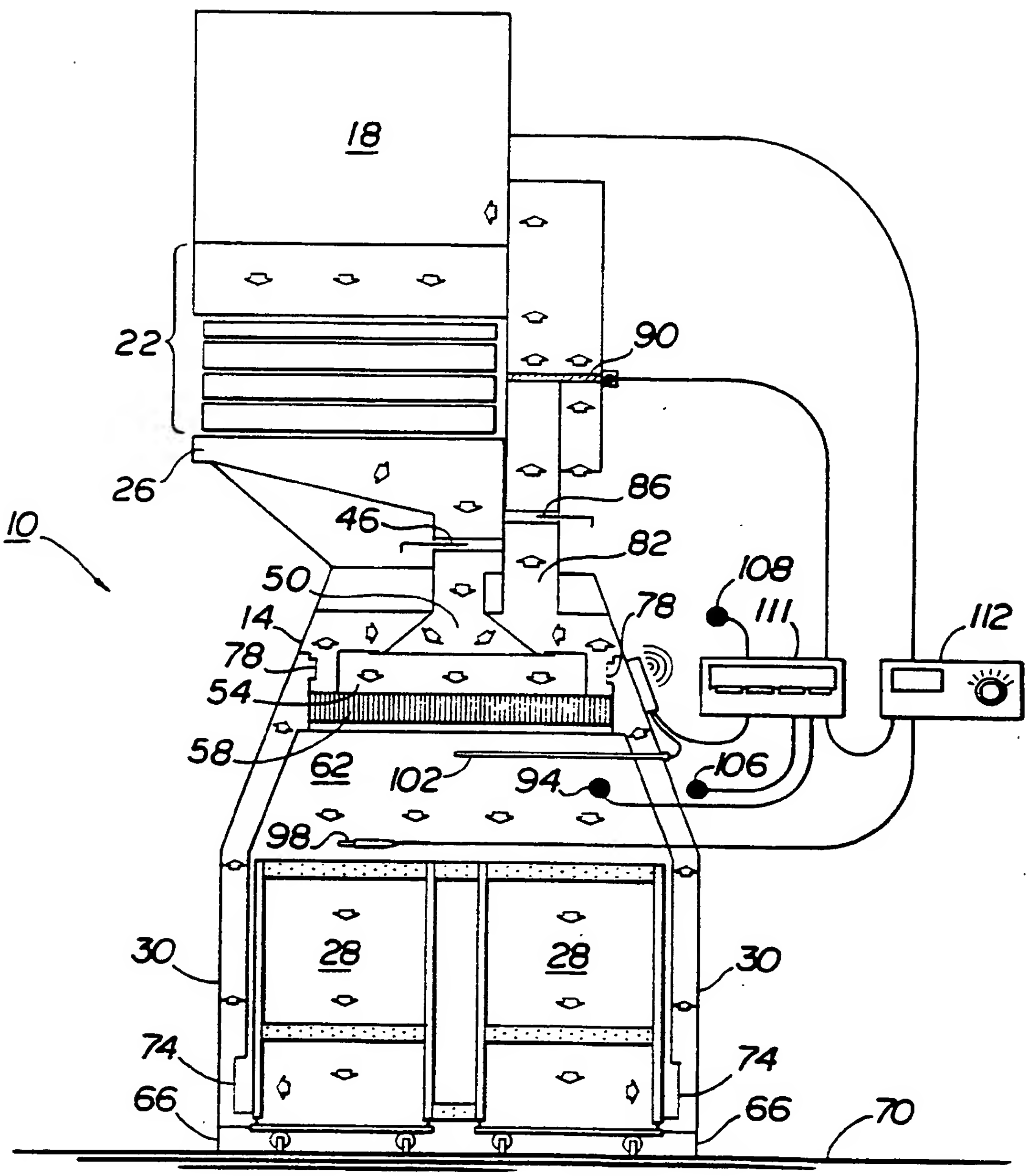
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FIG 2

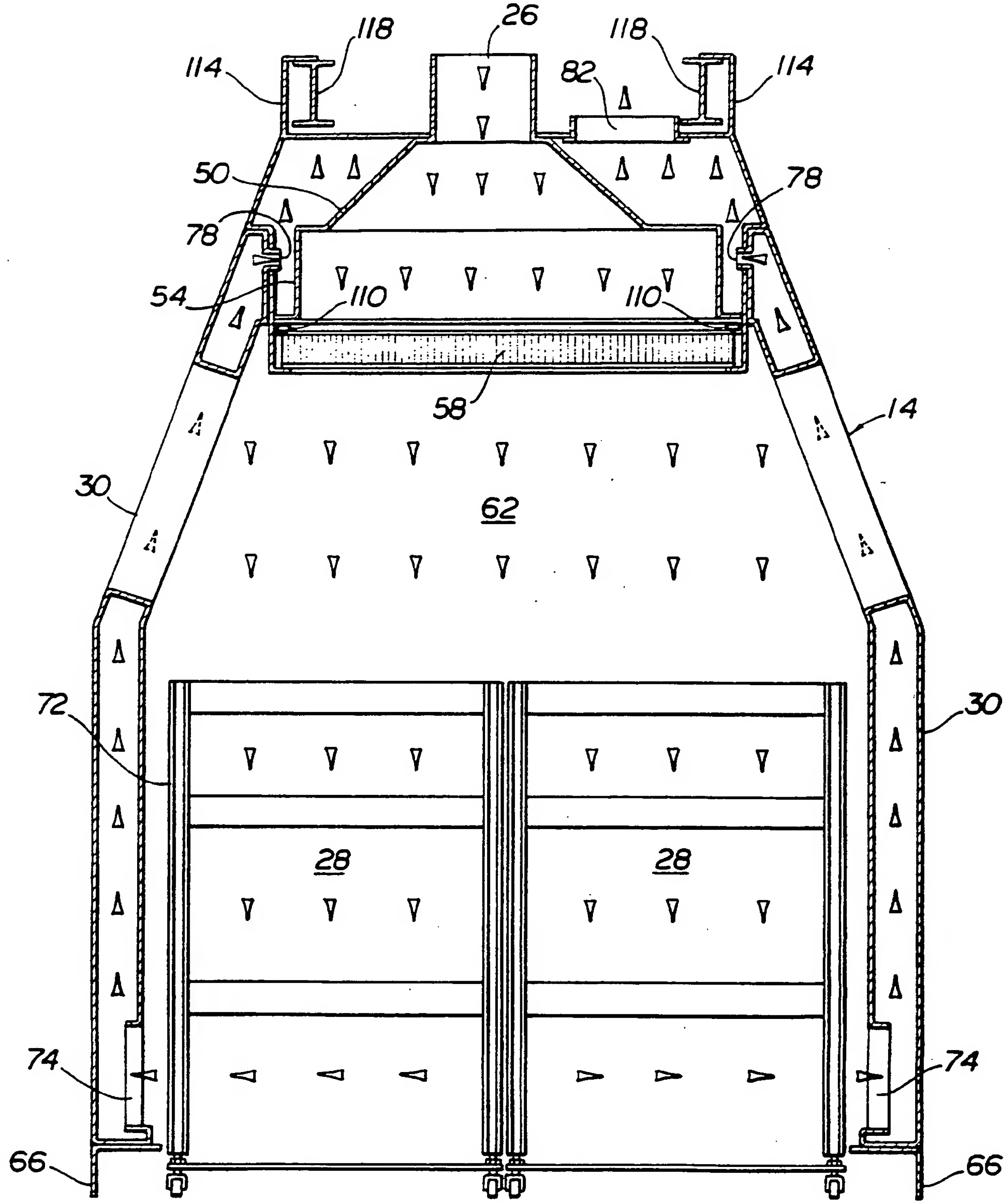
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FIG 3

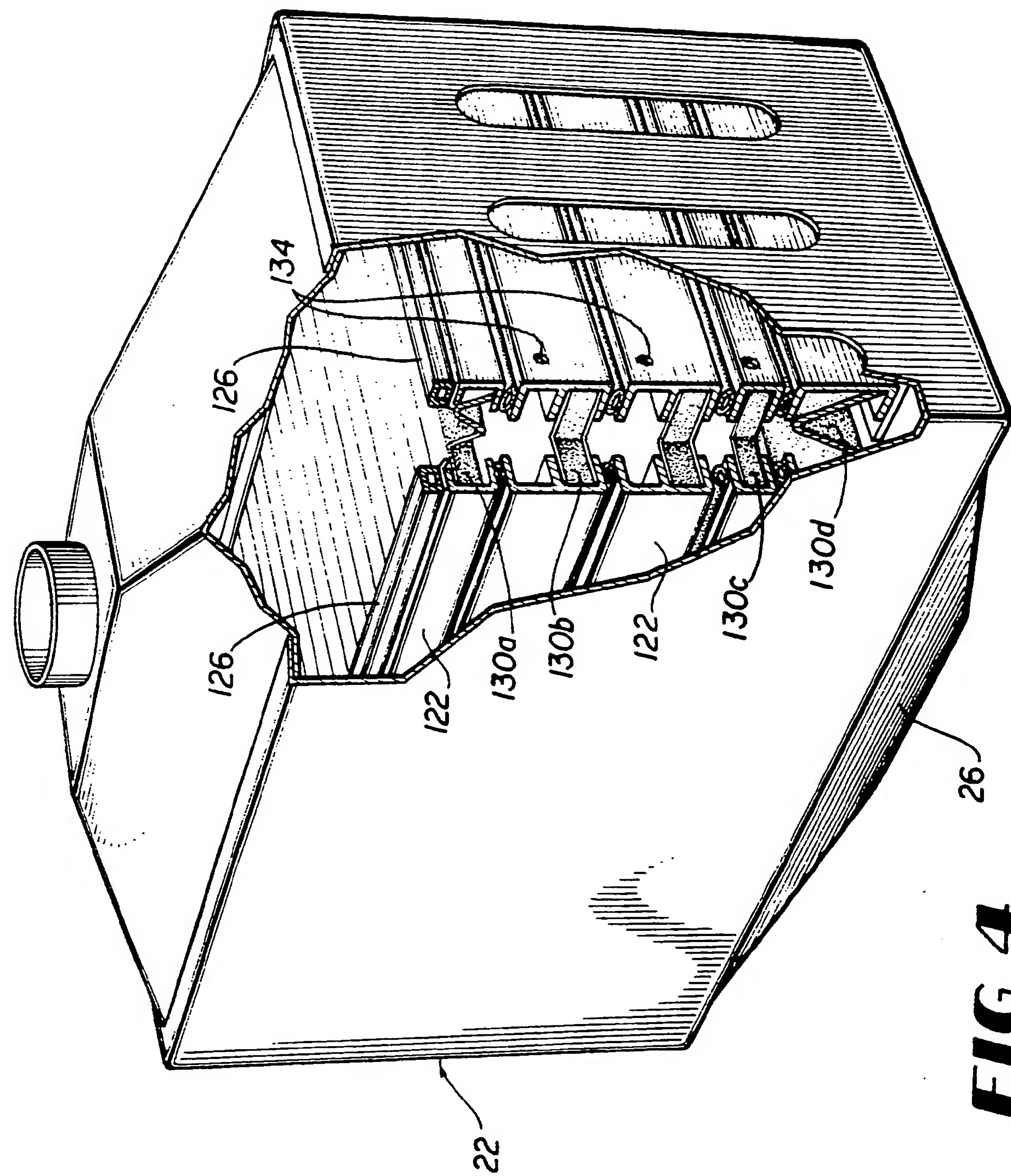


FIG 4

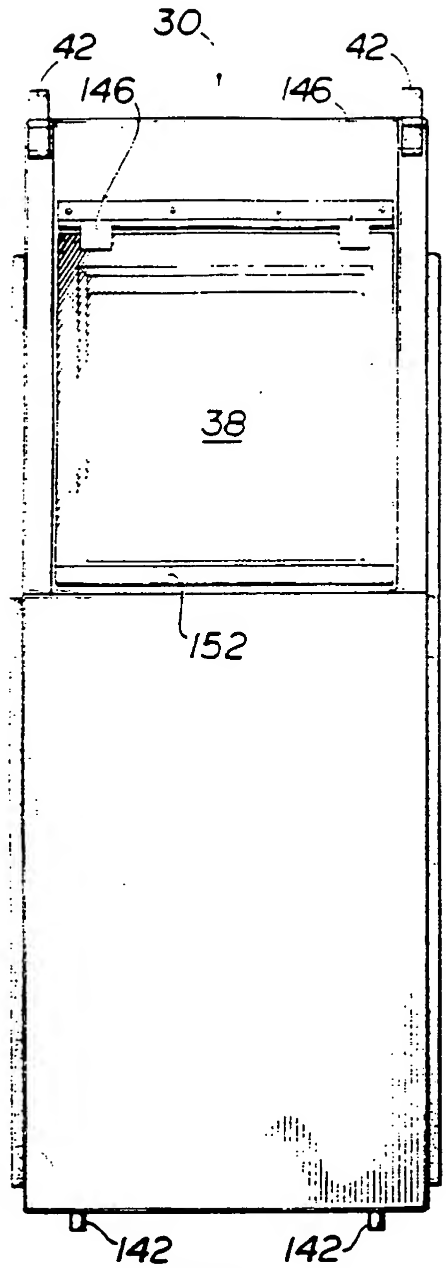


FIG 5

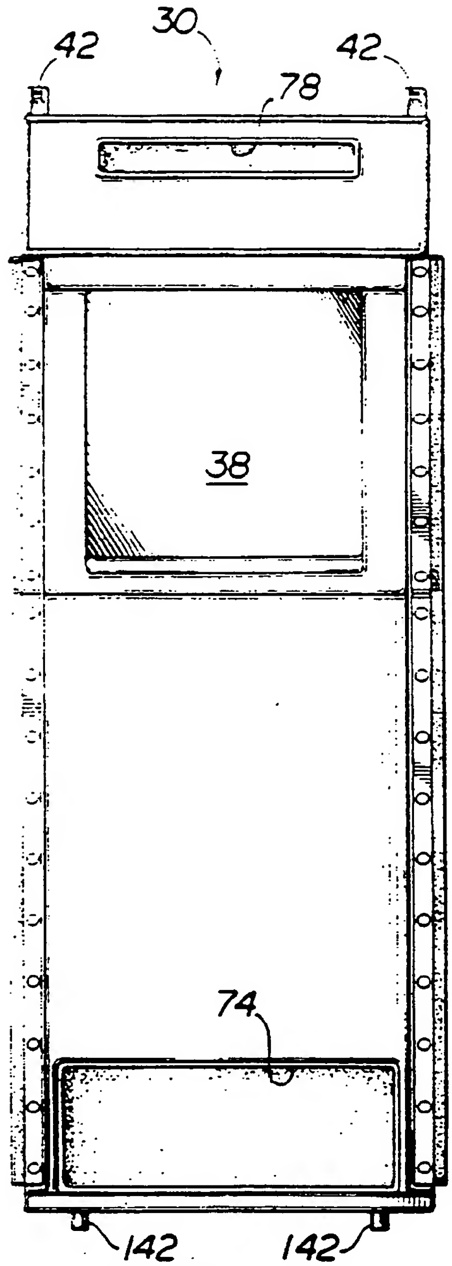


FIG 6

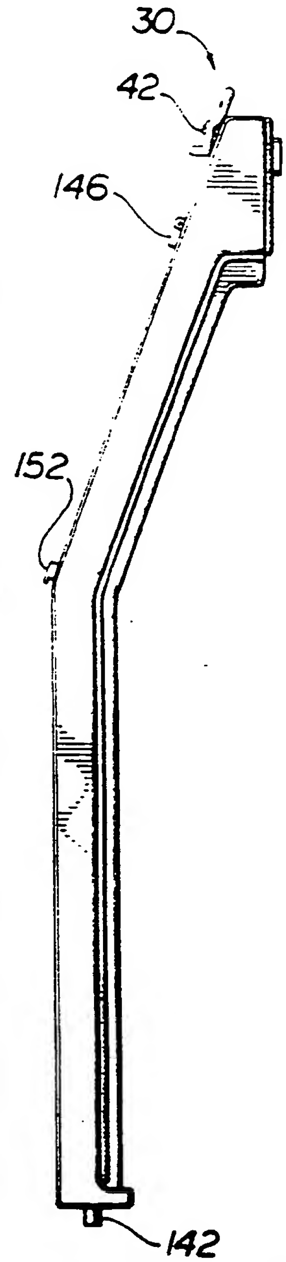


FIG 7

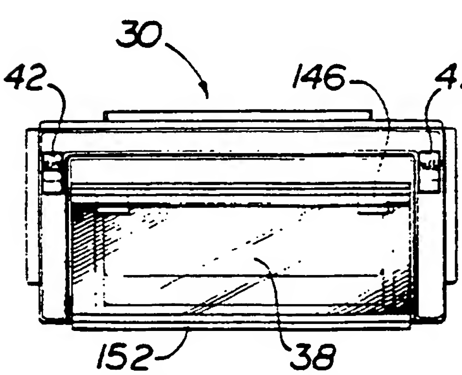


FIG 8

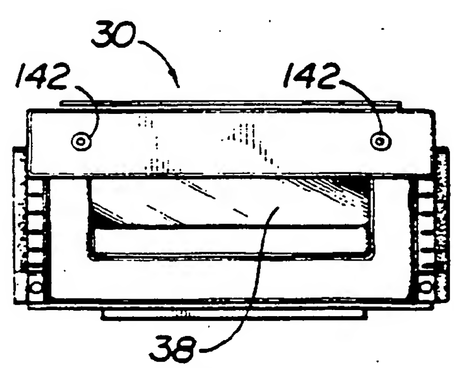


FIG 9

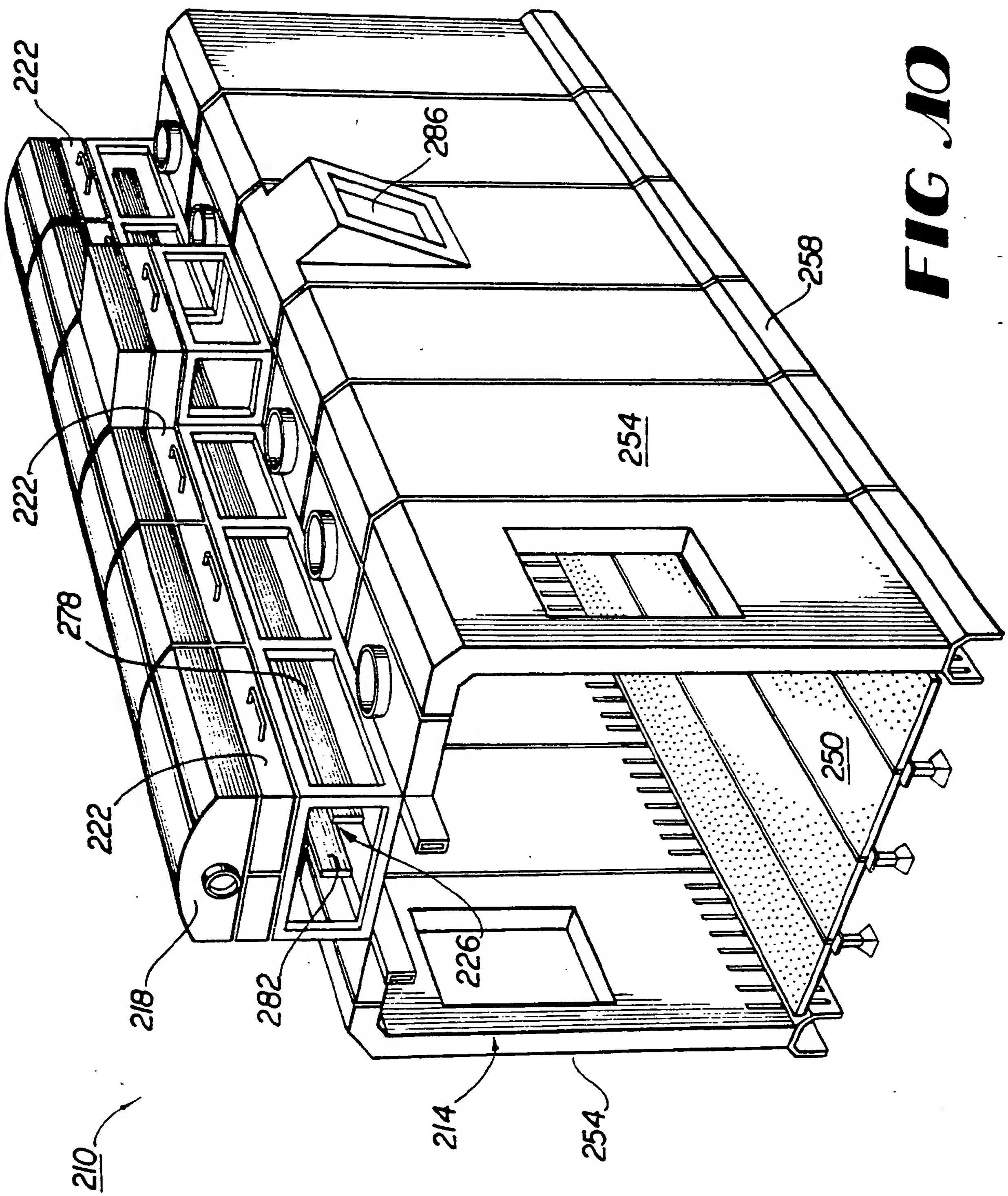
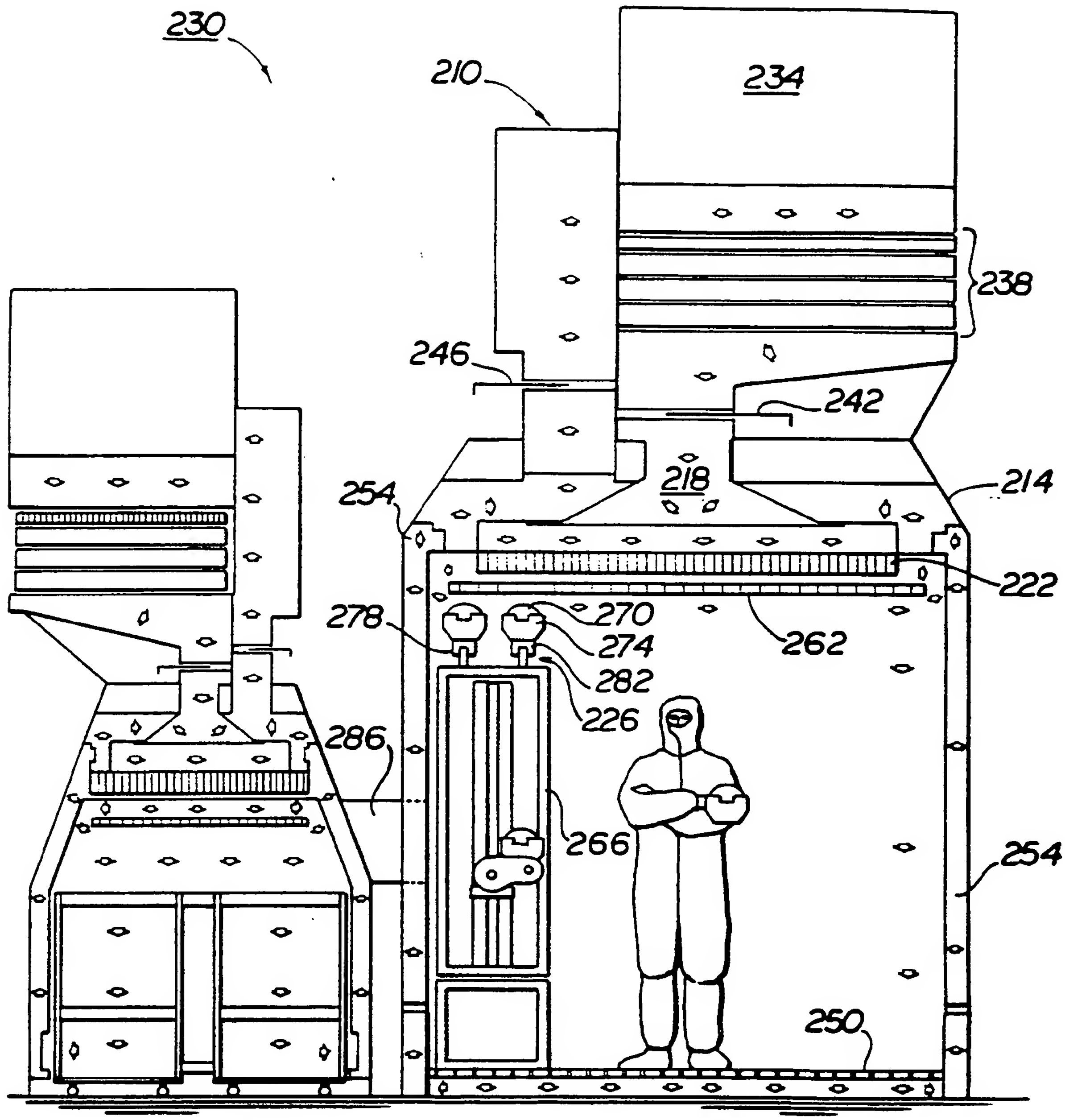


FIG 10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250

FIG 11

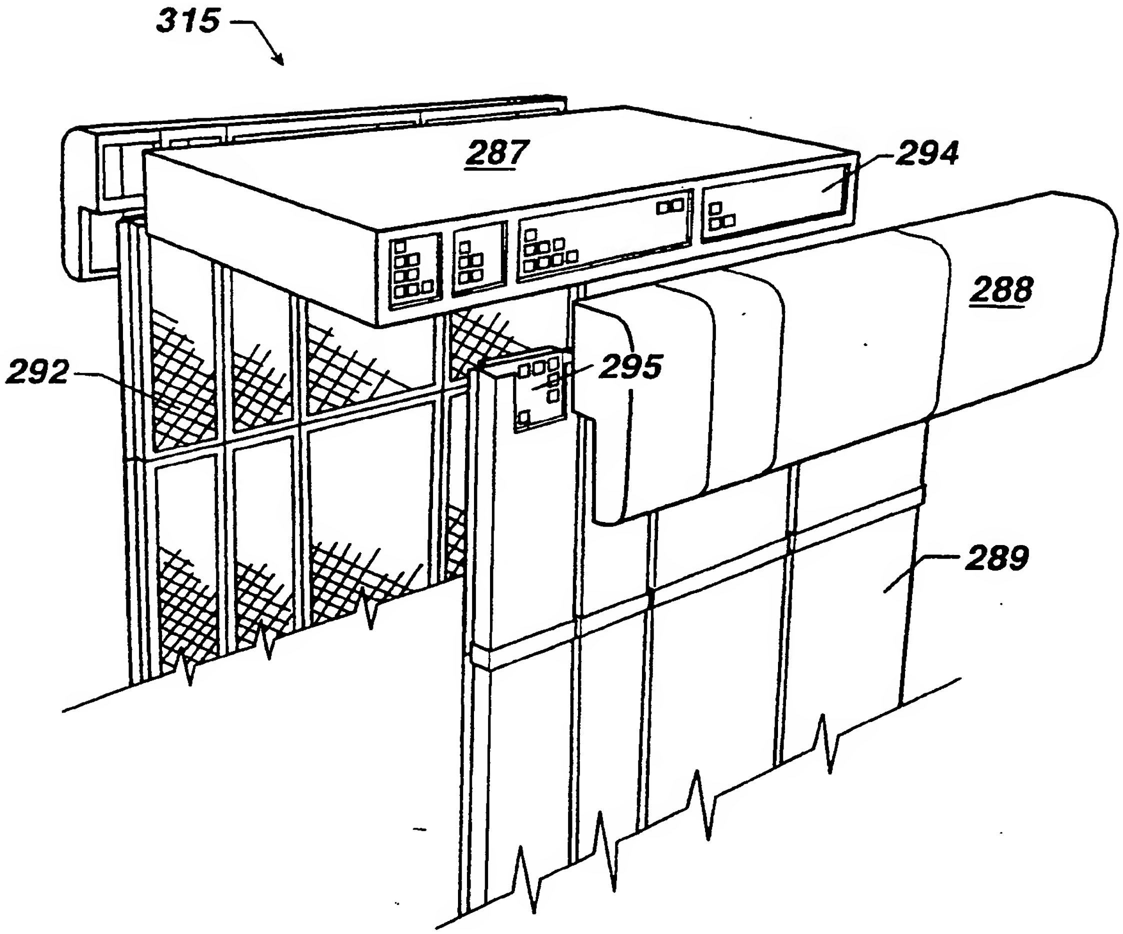


FIG 12

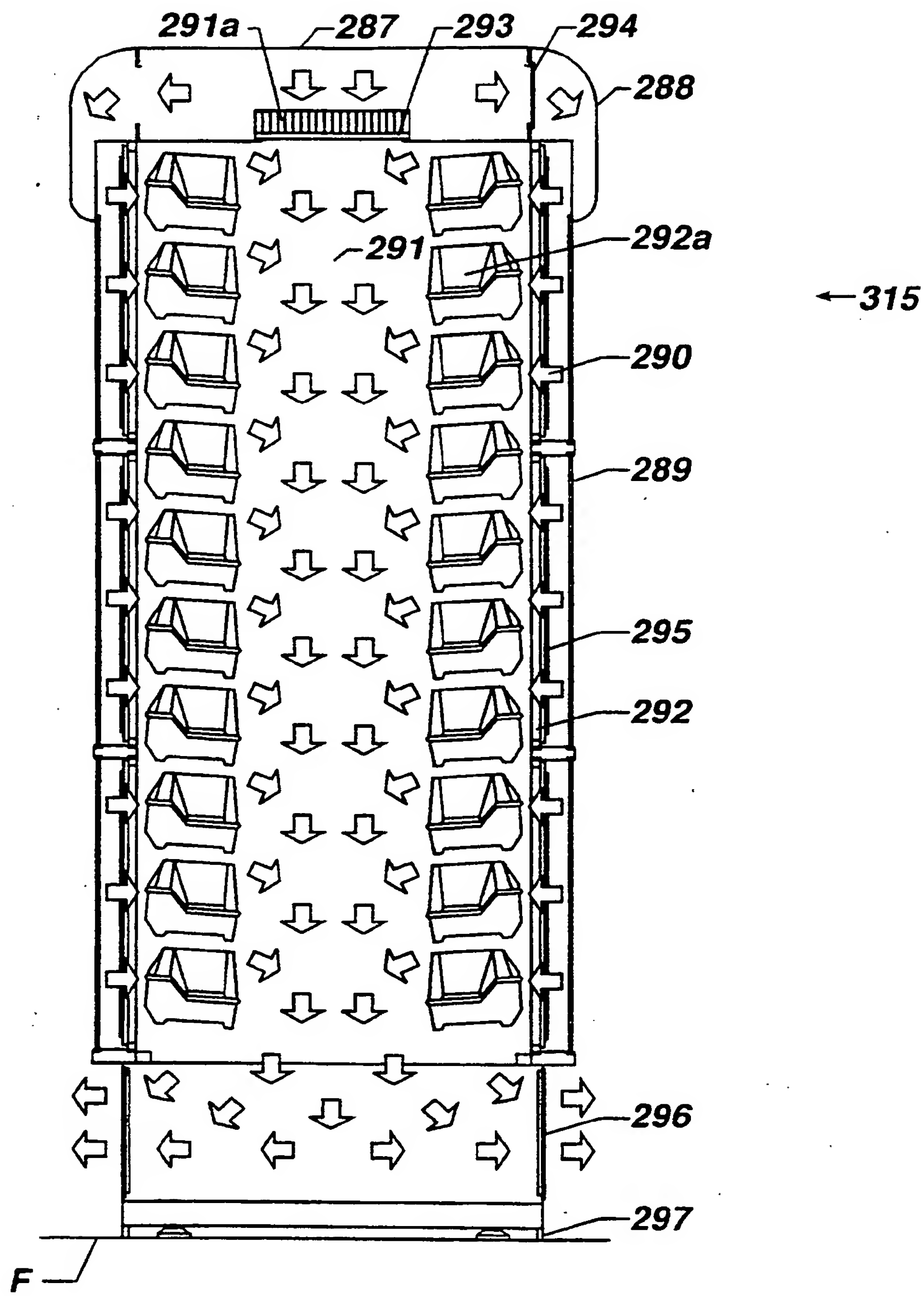
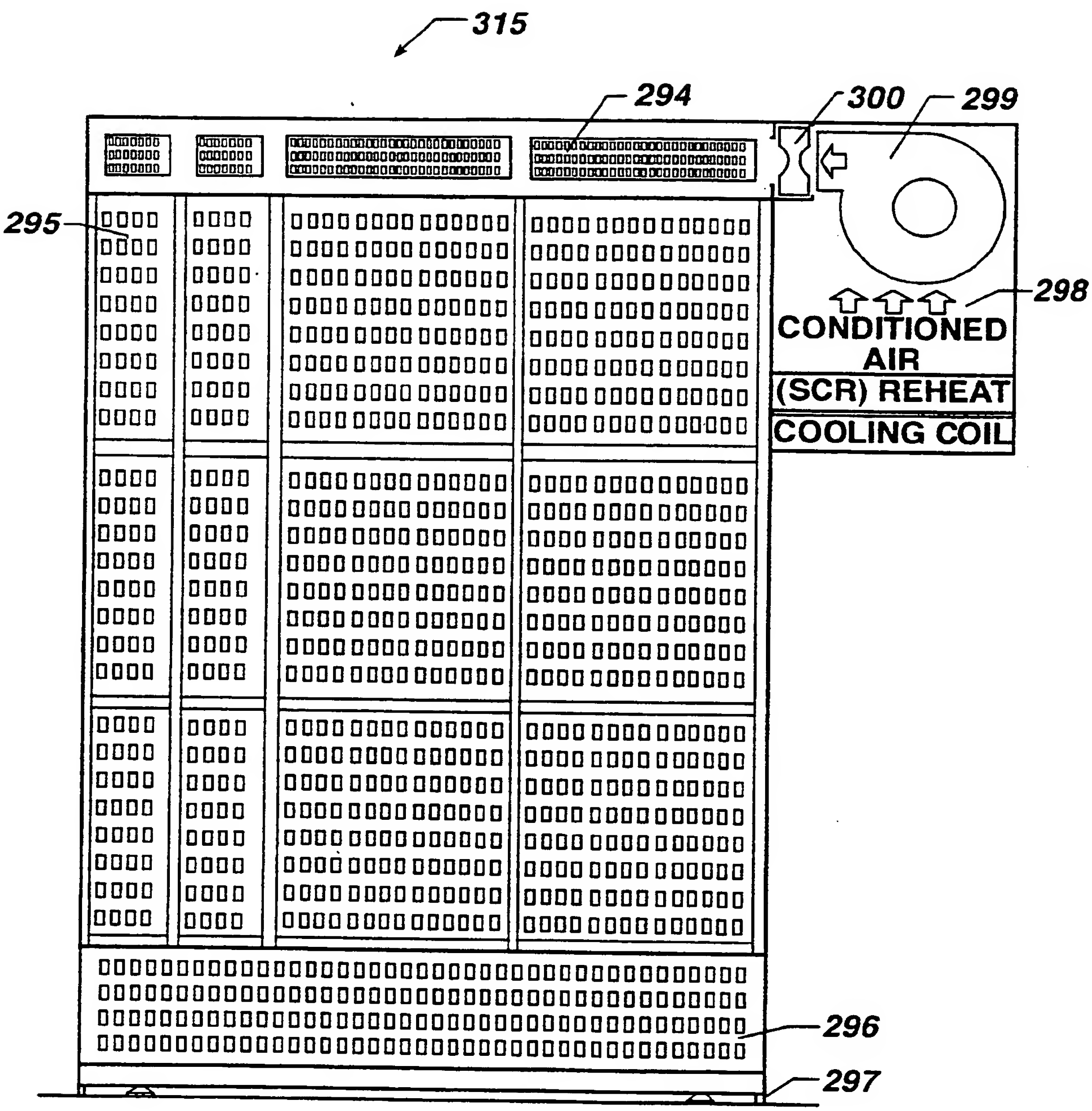


FIG 13


315
294
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CONDITIONED AIR
(SCR) REHEAT
COOLING COIL
296
297

FIG 14

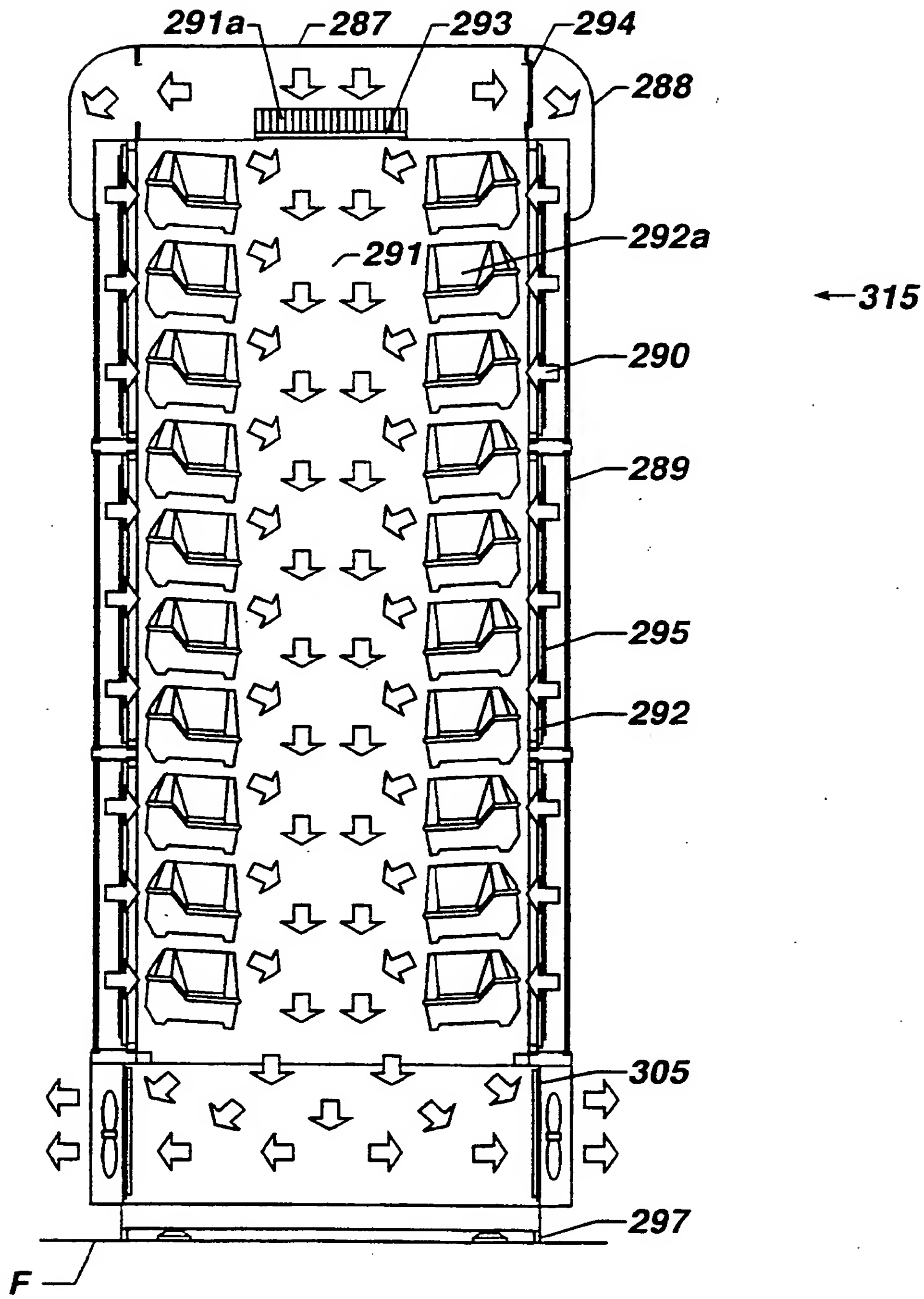
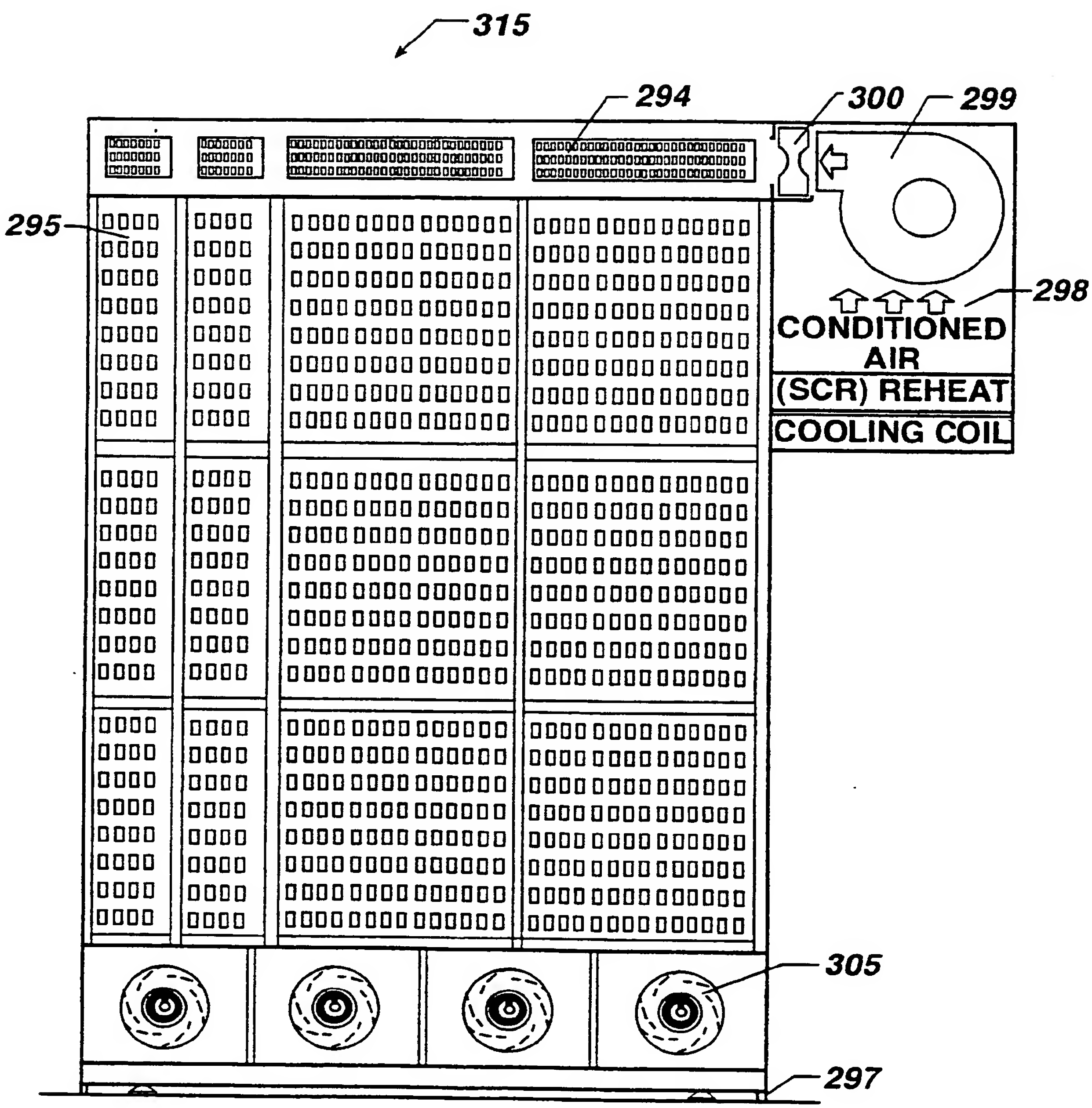


FIG 15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CONDITIONED AIR
(SCR) REHEAT
COOLING COIL
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297

FIG 16

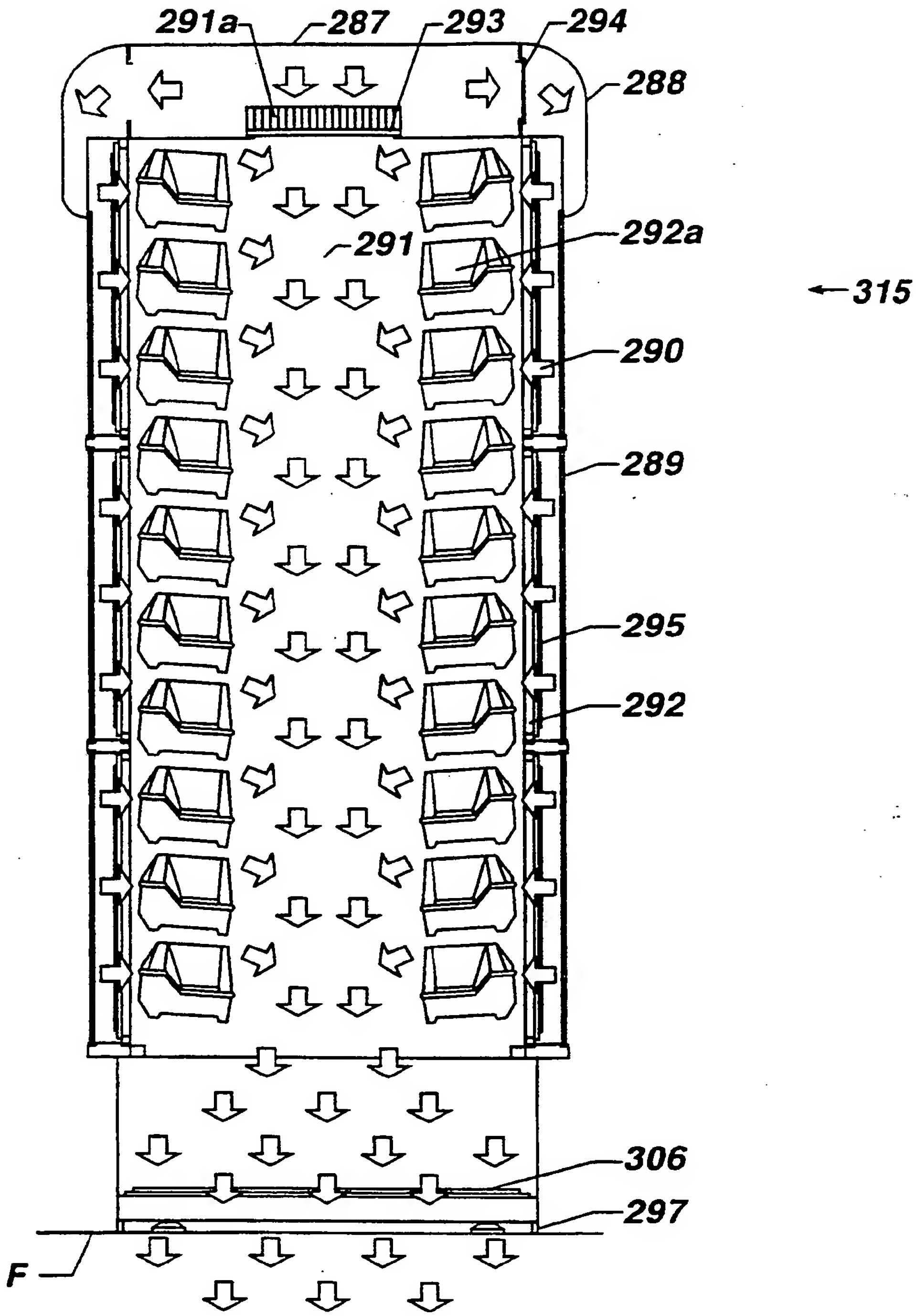
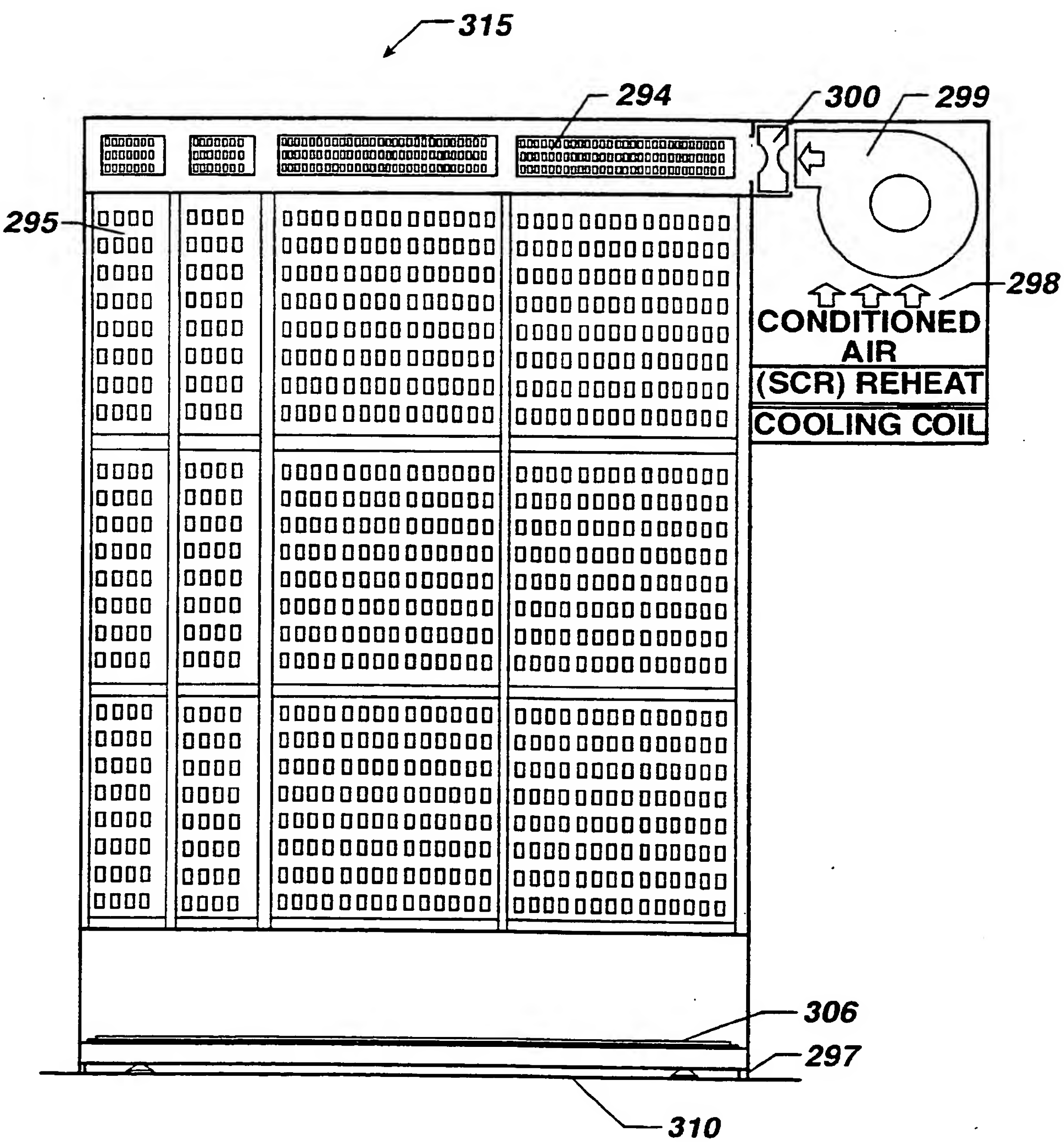


FIG 17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CONDITIONED AIR
(SCR) REHEAT
COOLING COIL
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FIG 18

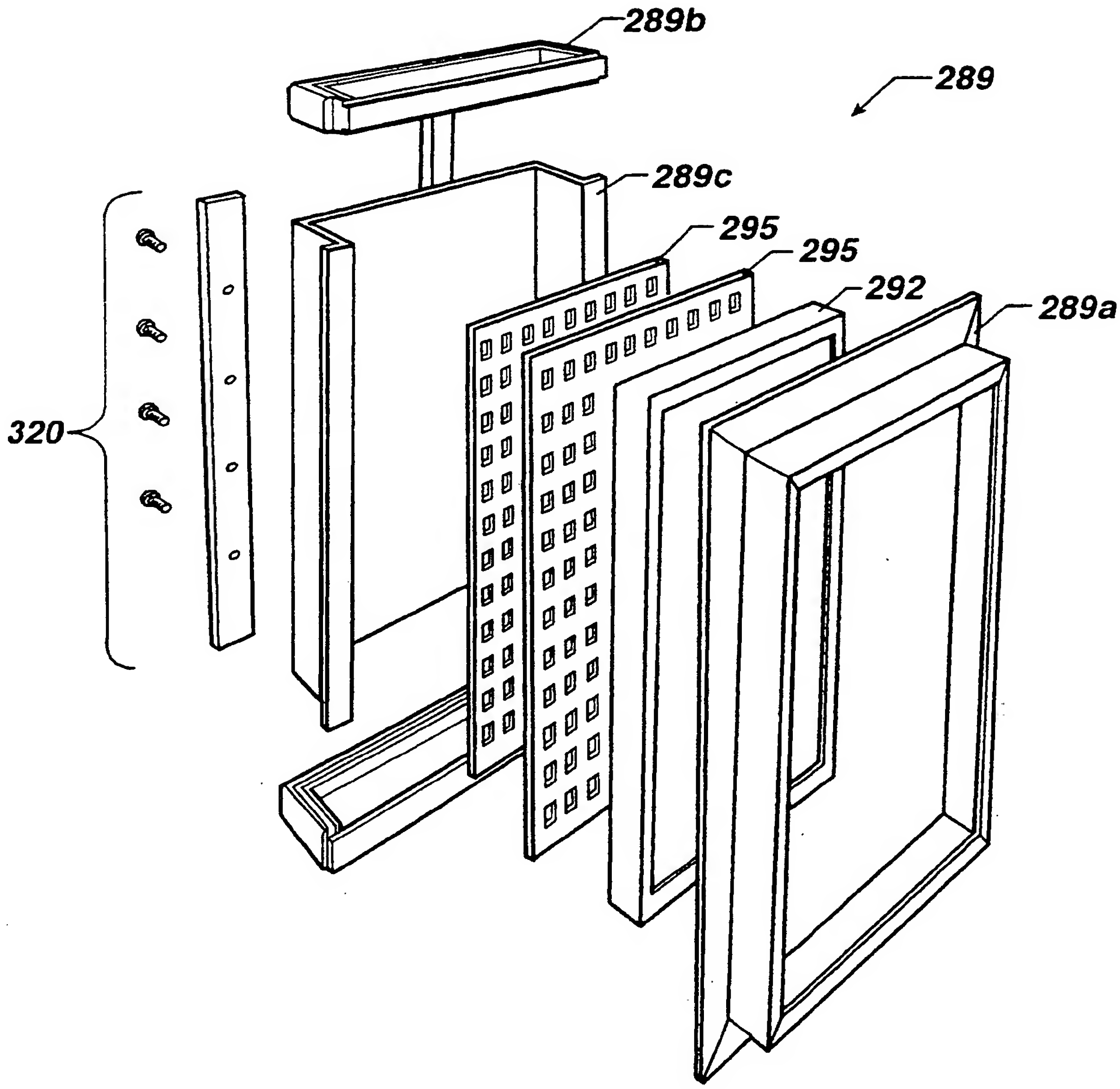

FIG 19

SUBSTITUTE SHEET (RULE 26)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US94/00900

A. CLASSIFICATION OF SUBJECT MATTER
IPC(5) :F24F 3/16
US CL :454/187
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 454/56, 57, 58, 61, 62, 187, 284, 298, 324, 334

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	CH, A, 577, 833 (LAUBER) 30 July 1976, see Figure 1.	1
X -- Y	US, A, 4,880,581 (DASTOLI et al.) 14 November 1989, Abstract.	2, 3 ------ 4, 5
X -- Y	US, A, 4,927,438 (MEARS et al.) 22 May 1990, Abstract.	1, 2 ------ 4, 5
X -- Y	US, A, 4,976,815 (HIRATSUKA et al.) 11 December 1990, Abstract.	2, 3 ------ 4, 5
Y	US, A, 4,666,477 (LOUGH) 19 May 1987, Abstract.	4, 5

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

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"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

27 MARCH 1994

Date of mailing of the international search report

MAY 04 1994

Name and mailing address of the ISA/US
Commissioner of Patents and Trademarks
Box PCT
Washington, D.C. 20231
Facsimile No. (703) 305-3230

Authorized officer
Harold Joyce
Telephone No. (703) 308-0274